DIE CASTING ENGINEER

THE SOCIETY OF DIE CASTING ENGINEERS, INC.
19382 JAMES COUZENS HIGHWAY
DETROIT 35, MICHIGAN

SDCE

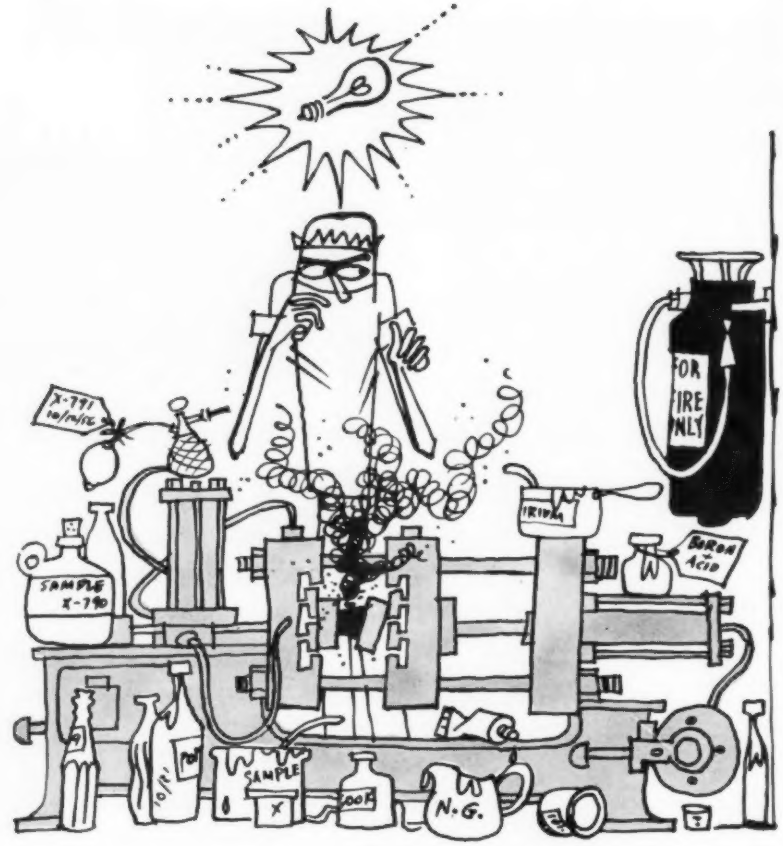
FIRST EDITION – MARCH, 1957

out of the blowpipe

Our newest 33X Die Slick for aluminum is having a real workout in the field. Reports are mixed: some swear by it, some are standardizing on it, a few are swearing at it. The enthusiastic ones say it's the best compound for aluminum they've tried. Some say it's no better than what they've been using.

What we look at is the ratio of good to bad reports. In 17 years of serving die casters, we know a hot item when we see one, and this one looks good!

Have you tried 33X on your aluminum jobs? You can try it without risking a nickel (used to be you could try it without risking a penny, but the cost of living has gone up). Here's how: *Order a gallon of 33X Die Slick.* Try it in your shop. If it isn't better than what you've been using, I'll cancel the invoice. You can't join the critics until you try some!



Don't try everything...try Die Slick!

Any die caster who is besieged by samples of die casting compounds knows what we're talking about. If you tried all the samples you get, you wouldn't have time to make castings! That's why many die casters use a Die Slick compound for most of their jobs. First, there is a proven Die Slick compound for every job, no matter what metal or alloy you are casting . . . no matter how large the part.

Second, continuing research and field testing makes new Die Slick compounds available. Where die casters get into trouble is in not checking with us when problems develop. Have you had trouble lately? Telephone Dayton, KEnmore 5114.

Die Slick is a registered trade mark of G. W. Smith & Sons, Inc.

DIE SLICK

used by die casters everywhere

G. W. SMITH & SONS, INC., 5403 KEMP ROAD, DAYTON 3, OHIO

DIE CASTING ENGINEER

VOLUME 1
NUMBER 1
MARCH, 1957

Official Publication of
THE SOCIETY OF DIE CASTING ENGINEERS, INC.

STAFF

CONTENTS

FEATURES

DEPARTMENTS

The DIE CASTING ENGINEER is published quarterly by The Society of Die Casting Engineers, Inc.—a society for the improvement and dissemination of the knowledge of the arts and sciences of die casting, the finishing of metals, and the allied arts. The DIE CASTING ENGINEER offers a concentrated coverage of management and engineering in the die casting and directly related industries.

Only advertising pertaining to die casting and finishing of metals and the allied arts is acceptable. The Society reserves the right to reject any advertising deemed objectionable for any reason what-so-ever.

The annual subscription rate is $3.50 for members and $6.50 for non-members. Single copies $1.50.

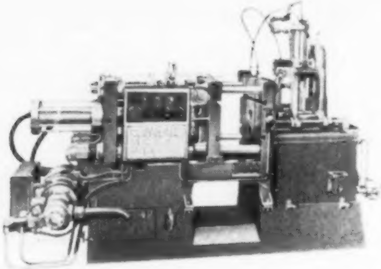
The Society of Die Casting Engineers and its editorial staff do not necessarily endorse signed articles or statements appearing in the DIE CASTING ENGINEER.

Printer: Ann Arbor Press, Inc., 317 Maynard Street, Ann Arbor, Michigan.

EXECUTIVE OFFICES — 19370 JAMES COUZENS HWY. — DETROIT 35, MICHIGAN
— UNiversity 4-9116 —

your answer to Profitable die casting production

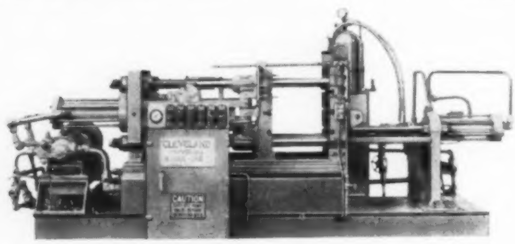
CLEVELANDS



Model 50 Cleveland
50-ton locking pressure*
Capacity: 2.6 lbs., aluminum
5.4 lbs., zinc

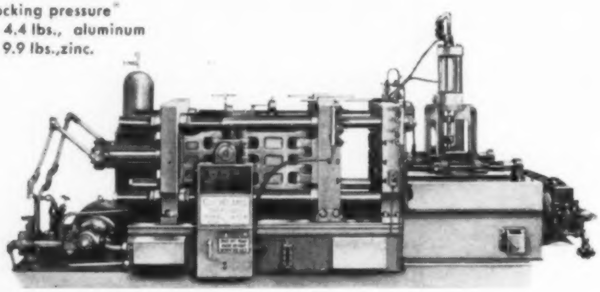
Shown here are several models in the line of Cleveland Universal Hydraulic Die Casting Machines...each one a champion in its class! Whether the casting size is large or small, there's a Cleveland that will fit your production requirements exactly and give you castings of precision quality at a highly profitable rate.

The nation's leading die casters rely on Clevelands for dependable performance. Find out now how Clevelands can improve your die casting production with money saved. Call in a Cleveland sales engineer. For complete machine specifications, write for bulletins.

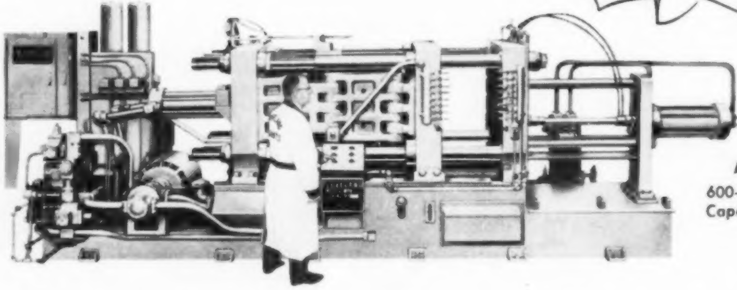


Model 200 Cleveland
200-ton locking pressure*
Capacity: 4.4 lbs., aluminum
9.9 lbs., zinc.

REMEMBER, CLEVELANDS CUT . . .



Model 400N Cleveland
400-ton locking pressure*
Capacity: 7.2 lbs., aluminum
14.5 lbs., zinc.



Model 600 Cleveland
600-ton locking pressure*
Capacity: 10 lbs., aluminum
25 lbs., zinc.

***Locking pressure strain gage tested.**

THE CLEVELAND AUTOMATIC MACHINE COMPANY

4916 Beech Street
Cincinnati 12, Ohio

SALES OFFICES: CHICAGO
CLEVELAND • DETROIT
HARTFORD • S. ORANGE

Manufacturers of a Complete Line of Single Spindle Automatic Screw Machines and High Pressure Hydraulic Die Casting Machines

From the first National President:

HISTORY
of the
S.D.C.E.

HARRIS SHIMEL is one of the outstanding leaders in the formation of The Society of Die Casting Engineers. As National President for the year 1955-1956 he led in developing new chapters and in the progress of the Society as a whole. He is now a National Trustee and is associated with the Toledo, Ohio chapter.

Mr. Shimel was born in Deavertown, Ohio, in February of 1906 and was educated in Ohio schools. He is a graduate of the General Motors schools of Factory Management and Basic Management and has completed the G. M. Dale Carnegie Course. The seven years following his graduation from high school were spent moving around the Midwest and South as a laborer, plumbers helper, steel worker, and automatic screw machine operator. On January 20, 1931, Harris Shimel began his career with the Chevrolet Bay City Division of General Motors. He recently terminated 25 years with Chevrolet Bay City after having reached the positions of foreman and general foreman of the zinc die casting operation during the last six years. His present position is Superintendent of Die Casting Aluminum and Forging with the Chevrolet Passenger Transmission Plant in Toledo, Ohio.

Mr. Shimel is also a member of the American Electroplaters Society.

Harris Shimel describes the founding and dynamic early history of the Society of Die Casting Engineers . . . . .

. . . ."IT IS JUST THE BEGINNING"

Historically the Society is a mere infant but the chronology and growth of the organization make interesting reading. Since its inception there has been nothing but firsts, with many more to come.

It all began way back in 1954 when George Griffenham, the present Executive Secretary of the Society, then a sales engineer doing research work on mold release agents for Mergraf Oil Company in the die-casting industry, asked where it was possible to get some basic information on die-casting. In the discussions that inevitably followed it was generally agreed that there was no organization in the Michigan area that met the need for the exchange of information among engineers, captive die-casters, suppliers and others associated with the die-casting industry.

George then selected 82 die-casting concerns at random from the Flint, Bay City, Saginaw and Detroit directories. To each he sent a questionnaire which generally explored the possibility of forming a local society of die-casters. Seventy-eight replies were received and from these, 11 organizations representing a cross-section of those polled were asked to send representatives to a preliminary meeting on Sept. 1st to explore the advantages of such a society.

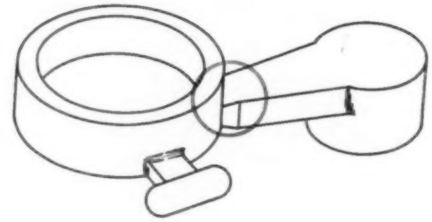
The response was gratifying and the following men met at the Park Shelton Hotel, Detroit, in what is now a historic meeting: Harris Shimel, Bay City Chevrolet; George Griffenham, Mergraf Oil Co.; J. R. Tucker and Richard Baribault, Alcoa; Martin Tufts and Richard Tinetti, A. C. Spark Plug; Marshall Aberle and John Miller, H. & M. Industries; John Matinello, General Die Cast Co.; Robert Cornell, Litemetal; and John Lapin, Saginaw Bay Industries. Following a lengthy, general discussion concerning reasons for the formation of a formal group, and possible conflict with existing organizations, it was agreed that a new organization was advantageous and necessary.

It is of interest to note a quotation from the minutes of that meeting. In an informal vote taken "to verbally determine whether or not an organization should be formed, 8 voted 'yes' and 2 voted 'perhaps.' "

(Concluded on Page 18)

Although freezing rate data is scarce, here is an . . .

Analytical Approach to Gate Design



by JOHN LAPIN

Chief Engineer,

Saginaw Bay Industries, Inc.

THE INCREASING DEMAND for higher strengths and as-cast pressure tightness in die castings makes it necessary to understand and apply certain casting principles not generally understood. Trial and error will probably never be completely replaced. However, a supplementary analytical approach based upon sound metallurgical and physical laws is desirous and extremely advantageous. The following treatment is intended to promote a line of thinking which will assist the trial and error process, and effectively reduce it.

A correctly designed die cavity requires that the vents must not be blocked off with metal until the cavity is filled. This is not always a simple problem to solve when designing a gating and venting system since there is some conflict in theory as to the exact flow pattern of metal in the cavity.[1] It is generally agreed that when the cavity *is* properly filled with respect to the vents, there is only a low back pressure in the cavity while the die is being filled. When the cavity is full the pressure rises rapidly, squeezing metal into the vents and actually extruding some solid metal into the overflow bobs if the metal near the bobs is partly solidified when the full pressure is exerted. During this rapid rise in pressure the metal in the cavity is "worked," gas inclusions are squeezed to a small size, and some plastic flow occurs.

The pressure reaches a maximum when the metal is completely static and while the gate is yet fluid enough to transmit pressure from the piston to the die cavity. The pressure on the plunger side of the gate has *no* effect on the casting after the gate is frozen since the solidified metal in the gate acts as a closed valve in the system. Furthermore, the casting must freeze under full pressure of the piston if it is to have maximum soundness. After the gate freezes, the effective pressure in the cavity drops to zero regardless of the pressure exerted by the die casting machine. If at this time the casting is still molten, the resulting product will have shrinks, shrink cracks, poor definition (misruns), and general porosity. This casting will be a crossbreed—somewhere between a true pressure die casting and a permanent mold casting made under the poorest feeding conditions.

The desired solidification under maximum pressure may be achieved only when the following factors are in correct balance:

A. Casting Volume, W
B. Controlling Wall Thickness, T_w
C. Gate Thickness, T_g
D. Time of Filling Cavity, θ

Furthermore, the gate velocity (V_g) must be such as to insure a good quality surface. According to Babington and Kleppinger,[2] the gate velocity must be over 100 feet per second for good surface finish. Other factors such as metal temperature, die temperature, metal cleanliness, lubrication, venting, the plane geometry of the gate, and its location, pressure, and ladling technique are not considered as variables in this discussion. Their importance is not to be overlooked, but they are to be considered optimum and constant in order to make clear the main idea of this presentation.

It is the writer's hypothesis that a rigorous relation exists between optimum casting quality (maximum internal soundness) and the variables herein set forth. The proposed hypothesis resulted from examination of the experimental data reported by Babington and Kleppinger and by the writer's own tests on die cast aluminum discs of varying thickness. Due to the paucity of experimental data on freezing rates of metal within the die, a hypothetical freezing rate was assumed, using one that appeared to give the most predictable results. The validity of this assumed rate was tested on the die cast discs and on production reel-shaped die castings which were torque tested to establish their soundness.

The mathematical relations among the several variables are based on the elementary concept that volume is velocity multiplied by the area of the cross section in motion. Some of the more important relations are shown below.

The gate width (L_g) is the linear dimension, in inches, of the gate at its junction with the casting. Its relation to the other variables is shown by:

$$L_g = \frac{W}{(\theta)(T_g)(V_g)(12)} \qquad (1)$$

W — Casting Volume — in³
θ — Time to Fill Cavity — sec.
T_g — Gate Thickness — in.
V_g — Gate Velocity — Ft./sec.

The minimum plunger velocity (V_p min) in feet per minute corresponding to a given diameter of plunger is calculated by:

$$V_p\,(\text{min}) = \frac{W(60)}{(\theta\ \text{max})(A_p)(12)} \qquad (2)$$

W — Casting Volume — in³
θ — Time to Fill Cavity — sec.
A_p — Area of the Plunger — in²

The maximum plunger velocity (V_p max) in feet per minute corresponding to a given diameter of plunger is calculated by:

$$V_p\,(\text{max}) = \frac{W(60)}{(\theta\ \text{min})(A_p)(12)} \qquad (3)$$

W — Casting Volume — in³
θ — Time to Fill Cavity — sec.
A_p — Area of the Plunger — in²

The minimum gate velocity (V_g min) in feet per second is calculated by:

$$V_g\,(\text{min}) = \frac{W}{(\theta\ \text{max})(T_g)(L_g)(12)} \qquad (4)$$

W — Casting Volume — in³
θ — Time to Fill Cavity — sec.
T_g — Gate Thickness — in.
L_g — Gate Width — in.

The maximum gate velocity (V_g max) in feet per second is calculated by:

$$V_g\,(\text{max}) = \frac{W}{(\theta\ \text{min})(T_g)(L_g)(12)} \qquad (5)$$

W — Casting Volume — in³
θ — Min. Time to Fill Cavity — sec.
T_g — Gate Thickness — in.
L_g — Gate Width — in.

θ min $= \theta$ max $- \theta$ gf, where θ gf is the Time in seconds required for the gate to freeze.

Since little published information is available on the absolute freezing times of metals cast in dies under pressure, we offer a working approximation. An aluminum casting with a wall thickness of 0.100 inches has a freezing time of 0.100 seconds. Magnesium freezes in ⅓ the time required for aluminum. This time varies directly as the square of the wall thickness. Thus, Table I presents the relative freezing times required for a range of wall thicknesses which include both casting walls and gates.

Table I

RELATIVE FREEZING RATES

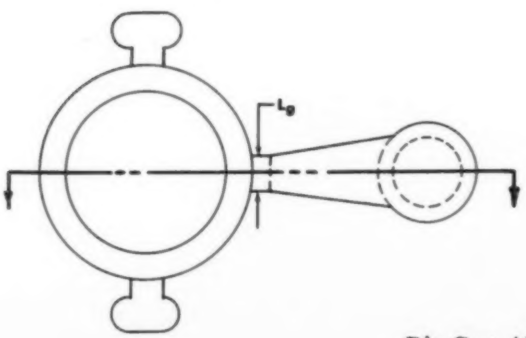
Wall Thickness (Inches)	Freezing Time (Seconds)	
	Aluminum	Magnesium
0.030	0.009	0.0030
0.040	0.016	0.0053
0.050	0.025	0.0083
0.060	0.036	0.0120
0.100	0.100	0.0330
0.200	0.400	0.1330
0.300	0.900	0.3000
0.400	1.600	0.5300
0.500	2.500	0.8300

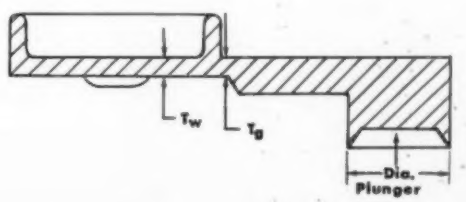
Using these relations in hypothetical cases will help to clarify the interdependence of the four variables.

EXAMPLE 1

Fixed Parts and Dimensions:

$W = 5.00$ in³
T_w — Controlling Wall Thickness $= 0.100$ in.
$T_g = 0.030$ in.





Die Cast Aluminum Test Disc

→

We know from Table I that the cavity must be filled in less than 0.100 seconds to avoid misruns. Babington and Kleppinger suggest that we should use a gate velocity greater than 100 feet per second. In fact, 200 fps will be used so that possible subsequent opening up of the gate will not reduce the gate velocity below the critical minimum.

For Gate Width (L_g):

$$L_g\,(\text{max}) = \frac{5.00\ \text{in}^3}{(<0.100\ \text{sec})(0.030\ \text{in})(200\text{fps})(12)} = 0.70\ \text{in.}$$

For Minimum Plunger Velocity (V_p):
Diameter of plunger = 2.0 in.

$$V_p\,(\text{min}) = \frac{(5.00\ \text{in}^3)(5)}{(<0.100\ \text{sec})(3.14\ \text{in}^2)} = 80\ \text{ft/min.}$$

However, if the cavity is filled in less than the minimum time (θ min) the gate will freeze before the casting is completely solidified.

$$\theta\ \text{min} = (\theta\ \text{max} - \theta\ \text{gf}) = (0.100 - 0.009) = 0.091\ \text{sec.}$$

Thus, for Maximum Plunger Velocity (V_p):

$$V_p\,(\text{max}) = \frac{(5.00\ \text{in}^3)(5)}{(0.091\ \text{sec})(3.14\ \text{in}^2)} = 88\ \text{ft/min.}$$

EXAMPLE II

The effect that an increase in gate thickness has on the gate width and the plunger velocity can be shown by *doubling* the gate thickness to 0.060 in. The thicker gate will result in a longer time interval between the complete filling of the cavity and the freezing of the gate. Since the time required for the gate to freeze will be 0.036 seconds, the minimum time in which to fill the cavity will be 0.064 seconds.

For Maximum Gate Velocity (V_g):

$$V_g\,(\text{max}) = \frac{(5.00\ \text{in}^3)}{(0.064\ \text{sec})(0.060\ \text{in})(0.70\ \text{in})(12)} = 155\ \text{ft/sec.}$$

This is a considerably lower value than the 200 fps for the 0.030 in. gate. The Minimum Gate Velocity is:

$$V_g\,(\text{min}) = \frac{(5.00\ \text{in}^3)}{(0.100\ \text{sec})(0.060\ \text{in})(0.70\ \text{in})(12)} = 99\ \text{fps.}$$

EXAMPLE III

The effect of increasing the casting weight without increasing the wall thickness may be shown by increasing the casting volume (W) to 10.00 in³. In this instance:

$$V_g\,(\text{max}) = \frac{(10.00\ \text{in}^3)}{(0.091\ \text{sec})(0.030\ \text{in})(0.70\ \text{in})(12)} = 435\ \text{ft/sec.}$$

However, if the casting volume is increased by doubling the wall thickness, then:

$$V_g\,(\text{max}) = \frac{(10.00\ \text{in}^3)}{(0.391\ \text{sec})(0.030\ \text{in})(0.70\ \text{in})(12)} = 101\ \text{ft/sec.}$$

V_p (max) and V_p (min) can be similarly established by substitution in relations (2) and (3).

The above calculations may be applied to magnesium as well as aluminum. The freezing time for aluminum shown in Table I was multiplied by 0.33 to correct for the lower heat content of magnesium. Gate velocities for equivalent surface quality must be 25% higher for magnesium than for aluminum.

(Concluded on Page 20)

MEET THE AUTHOR

JOHN LAPIN graduated from the University of Michigan in 1934 with a Bachelor of Science in Chemical Engineering. His first employment was with the Consumers Power Company as a chemist. He joined the Dow Chemical Company, Midland, in 1942 and was first associated with the Electrochemical Department. Transferred in 1946 to the Magnesium Department, he was principally involved in die casting research and development. Since 1952, Mr. Lapin has been with Saginaw Bay Industries, Inc. as Chief Engineer.

In addition to the Society of Die Casting Engineers, he is a member of the American Foundrymen's Society and the American Society for Testing Materials. He is active on the ASTM Committee (B-6) for Die Casting.

Goals of S.D.C.E. committee strive for die casting industry—

STANDARDIZATION

by Meyer R. Tenenbaum

THE SOCIETY HAS UNDERTAKEN the organization of a national committee which will devote its efforts toward the establishment of a group of machine standards. At an organization meeting on November 30, 1956 in Detroit — a group of 17 men from leading die casting areas and companies set up the mechanics of the group under Chairman Meyer R. Tenenbaum.

The major aim of the committee is to suggest those basis for machine comparison without infringing upon the design prerogatives of the builders of die casting certain standards which will provide for die interchangeability throughout the industry, and allow an intelligent machines. Emphasis is being placed on the problems imposed by a possible all out national defense effort which would pose many problems of adapting dies to various machines in many areas.

When the general scope and purpose of the committee has been resolved, and a definite plan of action prepared, it is proposed that the manufacturers of die casting machines will be invited to participate in and join the activities of the society committee. Precedent for such a group already exists in a joint industry committee of The Society for Plastics Industry (S.P.I.) and the manufacturers of plastic machines.

Three major task groups are studying various aspects of the standardization program. These groups are considering such items as size and location of clamping slots or holes, hole pattern, knockout hole pattern and location of the metal injection system with relation to the center of the platens.

Included in the items of consideration for standard rating and nomenclature are clamping tonnage, distance between bars or beams, maximum and minimum shut height, location of injection nozzle or sleeve, length of stroke, weight of standard shots, nozzle sizes and radii, available pressures, and a number of other pertinent items.

Progress is expected to be steady although slow, but it is hoped that the formation of study groups in all our chapters will provide sufficient new and useful data to enable the main committee to operate with minimum delays.

■ ■ ■

SOCIETY OF DIE CASTING ENGINEERS

BOARD OF DIRECTORS

PRESIDENT
HARRY E. ERIKSEN
Chrysler Corporation

VICE PRESIDENT
HARRY CAGIN
The Halex Die Casting Co.

EXECUTIVE SECRETARY
GEORGE F. GRIFFENHAM
Mergraf Oil Company

EXECUTIVE TREASURER
MEYER R. TENENBAUM
Lester-Phoenix, Inc.

DIRECTOR
HARRIS R. SHIMEL
Chevrolet Passenger
Transmission Div: G.M.C.

DIRECTOR
WILLIAM VAN RAAPHORST
American Mold Engineering Co.

DIRECTOR
DEAN L. ROCKWELL
Clifford-Rockwell Co.

COMING SOON: CHEVROLET DIE CAST TRANSMISSIONS

S.D.C.E. PLANS TOUR THROUGH NEW PLANT

The Society of Die Casting Engineers is conducting a fascinating and informative plant tour through the General Motors Chevrolet Passenger Transmission Plant in Toledo, Ohio. The trip, scheduled by the national offices, for members and guests, is planned for early April.

The Chevrolet Passenger Transmission Plant, the newest addition to the Chevrolet Division of General Motors, manufactures the new Turboglide automatic transmission using the most modern methods available. Under the direction of Plant Manager Grosvenor Swift, the plant includes a special combination of ladling, parts transfer, and waste removal techniques in conjunction with the best known methods of die casting to form a new concept in die casting operations. The total operation is pictured as a continual flow of molten alloy to the die casting machines and a continual flow of finished castings and trim waste from them. Storage and shipping costs are reduced to a minimum by use of intra-plant conveyor systems. The die casting operations are adjacent to the finish machining and final assembly operations where the new transmission units are completed. Although the machines, methods, and materials are identical to those being used in die casting shops all across the country it is the parts transfer organization which makes this plant so unique.

The finishing operations on the die cast parts are executed using the latest word in automatic machines and parts handling equipment.

A highlight in the plant tour will be the modern, well-equipped chemical and metallurgical laboratory adjacent to the die casting operations. ■ ■ ■

VACUUM DIE CASTING . . .

by DAVID M. MORGENSTERN

THE PAST DECADE HAS SEEN a large upsurge in the use of die castings on a world-wide basis. With this increase in the volume of die casting usage, there has been a corresponding increase of the many difficulties besetting the die casting foundry. Where previously the user of die casting was satisfied with a fairly simple casting of not too fine a surface finish, the advent of the modern high pressure, high speed die cast machine, with its great potential for production of dense, tight, superior finish die castings, has made the die casting user quite critical in his demands for the quality of the product.

Although there have been many improvements in both the alloys used and in the design and construction of modern die cast machines, certain limitations have always beset the die casting industry, and still exist to this day, in spite of all the improvements we have seen in the past ten years.

Air is major problem.

In the older, permanent mold process, entrapment of air is not a very serious problem because, as metal is poured into a die cavity by gravity, the slow filling up of this cavity by molten metal gives the entrapped air a chance to be pushed out ahead of the molten metal, to be expelled through proper vents or risers. In pressure die casting, the very thing that makes this process so practical—the extremely high speeds and high pressures of injection of molten metals into the die—also creates the problem of porosity, because when metal is injected through the thin gate into the die cavity, the metal is broken up into a fine spray. This spray is then followed through by a flush of filling metal. The spray coats the interior of the die surface and any air vents that may have been put in to remove air, effectively sealing off any passages where trapped air might be expelled. The major volume of air is still trapped within the casting by the rapid chilling of the molten metal upon the interior die walls.

Pressure reduces porosity.

In order to minimize the effects of this porosity, great injection pressures are introduced to highly compress this trapped air into small enough cavities that do not detract from the practical use of the casting. However, any die casting is still made up in cross section of a tight, dense skin, surrounding a porous structure of metal with its entrapped air. This will give rise to many difficulties, such as entrapment of plating solutions, blisters forming during finishing operations and porosity in castings which are detrimental to various uses. Also, this porosity has been the reason for the non-uniform physical characteristics of a die casting, versus the more uniform physical characteristics of a permold casting.

Die preparation costly.

A great deal of the cost of die castings is found in the expensive preparation of die cast dies for practical running of suitable quality castings. An average die casting die requires a great deal of cut and try work to determine the proper vents and overflows to minimize air entrapment. Many times it is almost as costly to try out and break in a die properly as to build a die in the first place. The necessity of adding overflows and changing runners to the die cavity to obtain proper heat balance in the die may set up conditions within the die which cause further air entrapment, due to the ricochet and swirling of metal flow. We are, therefore, caught between two opposing forces, and the final development of die layout and treatment of the die is a result of a compromise which may or may not give us the desired results.

Vacuum method is answer.

Since the inception of the die casting technique, there has been a constant search for the most obvious tool to eliminate this problem. That is, for a way or technique in which to die cast with the dies under a vacuum. This has been done many times on a laboratory basis and proven out to be the ultimate answer for the removal of trapped air. Die cast engineers have tried many schemes and ways to impart vacuum in the dies since laboratory experiments have shown that if the dies could be properly evacuated, the injection pressures needed to produce fine castings could be greatly reduced, since it is quite obvious that a large percentage of the injection pressure of a die cast machine is dissipated merely in the compression of air into and through a die casting. As a result of this, injection pressures have been increasing in design of machines, and as a result, locking pressures have had to be made correspondingly greater. This constant trend to larger and heavier machines could be arrested by the use of the vacuum technique, if a practical way of applying the vacuum technique could be found.

In examining the patent literature, it is found that

. . . TODAY AND TOMORROW

VICE-PRESIDENT
Nelmor Manufacturing Corp.

the activity of inventors has been quite prolific. However, none of these schemes has been fruitful or practical. Upon examination, it will be seen that practically all of these ideas have been centered upon one central plan. The basic plan has been to close the dies, then by various means, such as slides, moving core pins or special valves, to evacuate the die and then inject the molten metal into the die. Due to the very nature of the die casting process, it is a foundry process with its heat and molten metal problem. Many of the schemes which look good on the drawing board become impractical upon application to the actual foundry floor.

In the Nelmor VACUCAST system the approach to this problem has been attacked from a different angle. In the VACUCAST system, a complete enclosure, or hood, is built around the platen area of the machine. The hood is built in two sections—one section surrounding the moving platen of the machine—the other section surrounding the fixed platen of the machine. The mating surfaces of these hoods are equipped with a suitable shielding device, and enough telescoping action is built into the hoods to allow for variation of die heights. The basic improvement of the hood is that the machine upon closing, closes up the mating surfaces of the hood while the die faces are still some distance apart. At this point a massive vacuum is introduced from an accumulator storage tank and the die continues to close up and be fed with metal in a completely evacuated atmosphere. This alleviates the necessity of putting shields upon the die faces or worrying about the problem of flash or escaping metal sprays. In fact, the hood becomes an enclosure which adds to the safety and cleanliness of the operation.

Valve controls metal flow.

To prevent metal from being drawn up into the dies in the hot chamber machine, which is at present used for the manufacture of zinc alloy castings, a suitable valving device is built in over the feed hole port which permits metal to be fed into the charging cylinder of the injection system. This valve is operated in cycle with the evacuation and injection cycles of the machine so that the feed port is closed off from the atmosphere while vacuum is being drawn, and no metal can be brought up into the dies inadvertently. After vacuum has reached its proper level of intensity, the shot is made and the vacuum is then removed by the opening of an atmosphere intake valve. The entire process is synchronized automatically with the necessary timers and limit switches, so that it becomes completely automatic in operation.

Because of the large size valves and orifices used, the evacuation cycle is practically instantaneous, taking place in a very small fraction of a second so that there is no slow down of the machine in its operation. Because there is no entrapped air in the casting, the holding time necessary to have the casting solidified before ejection is cut considerable so that castings can be ejected much sooner than heretofore, thereby realizing an increase in the cycle speed of the machine. *In practical operation, this increase in cycle speed will amount to as high as 25 per cent of the overall cycle time of the machine.*

Proper access doors have been arranged in the hood so that hydraulic cylinders for core pulls and slides can be installed in the hood. The hoods are arranged so that by very simple locking devices the hoods can be removed in a matter of a few minutes for servicing and installation of dies.

Cold chamber process improved.

The vacuum system, as applied to the cold chamber machine used on aluminum and magnesium, has brought forth another important development in that the vacuum is utilized for the pulling up of metal directly from the furnace into the charging cylinder so that the need for hand ladling or auxiliary automatic devices is eliminated. Since the metal is forced into the cold chamber by means of atmospheric pressure, the interval of time needed to fill a charging cylinder is well under a second, so that metal can be run without any temperature loss or exposure to atmosphere. This makes the running of low silicon alloys practical. Since the metal is charged into the die under vacuum and is drawn from the center of the aluminum holding furnace, there are no oxide inclusions in the casting. The resultant casting, free of silicon and oxides, is readily anodizable. The finishes obtained from anodizing on these castings are equal to anodizing that can be done on sheet or extruded aluminum, opening up an entirely new field for the application of aluminum die castings.

The effect of air compression is magnified in the cold chamber machine since the cold chamber machine normally has a volume of air in the charging cylinder which must be compressed. By evacuating air, the injection piston speed is greatly increased, giving more resultant force for compacting the metal into the dies.

Metallurgical improvements are very marked. Not only have the physical results been improved, but the variation of results in runs of castings are stabilized

(Concluded on Page 22)

Casting Around

by THEODORA SIMONEAU

ASK ANY MAN in the engineering field how he feels about women in his line of work, and he will promptly and emphatically tell you, "They don't know a bolt from a screw or an allen wrench from a monkey wrench," and "What do they understand about tension or stress, veri-drives and pulleys, or hydraulics?" Whether it's die casting, mechanical, civil, or electrical, a woman has no place in engineering. I disagree! Now don't get me wrong, fellows; I'm not saying the little woman should go out and become an engineer, but at least give her credit for having the intelligence to understand the basic principles of engineering. She may not know the technical names of tools or the correct method of handling them, but many a woman has made the washing machine run longer, or a table or chair steadier with bobby pins, hammer and nails, screws, and the like. Meanwhile, hubby makes with the excuse he doesn't "have the right tool for that particular job." Bet it's happened in your home, too!

Working together is essential in any job. Being able to turn to your fellow worker for help and know he can be counted on is a great boost to your morale. I've run into men who wouldn't help another fellow, much less a woman; and then again, here at work, there are men who go out of their way to help. I admit there *are* times when I wonder if I should have taken up knitting instead.

I carry coffee, do dishes, dust furniture, pick up after the men, empty ash trays, file, run errands, and perform numerous other duties plus my regular duties of engineering drawing, technical illustrating, and working in the shop sketching parts of the machines. One more step has been taken by a woman in a man's field, and although we are sometimes rebuffed and made to feel unwanted, we are slowly breaking the all-male barriers that have been built up. Given the chance, I feel that women have a definite place in engineering. ■ ■ ■

MISS SIMONEAU first became interested in engineering at eighteen while working for the Dennison Manufacturing Co. in Marlboro, Massachusetts. She is a graduate of the Minneapolis Technical Institute in Mechanical Engineering. "Teddy" is now employed in Minneapolis by the O. W. Kromer Co., manufacturers of power sprayers, hy-rows, and seed treaters. She has worked with them since Dec., 1955 as a Junior Engineer. Her latest assignment has been technical illustrating.

Miss Simoneau has been attending the University of Minnesota, at their Institute of Technology, and is a student member of the Society of Agricultural Engineers.

SDCE HISTORY

(Concluded from Page 7)

Temporary officers were chosen—Harris Shimel, Chairman; Geo. Griffenham, Sec'y; Art Tinetti, Treas.; and John Lapin, Recording Sec'y. The Sec'y was instructed to draw up preliminary by-laws for presentation at the next meeting. Each of the group was urged to contact other interested individuals and stimulate interest in the first general meeting scheduled for October 4th.

It was held at the Veteran's Memorial Building in Detroit where some 54 people gathered to eat a buffet dinner before formally organizing the Society. Officers were elected as follows:

President	Harris Shimel, Bay City Chevrolet
Vice-President	Marshall Aberle, H. & M. Industries
Secretary	George Giffenham, Mergraf Oil Co.
Recording Sec'y	John Lapin, Saginaw Bay Industries
Treasurer	Arthur Tinetti, A. C. Spark Plug
Librarian & Historian	Meyer Tenenbaum, Lester-Phoenix Machine Company
Trustee	Harry Eriksen, A.C. Spark Plug
Trustee	John Miller, H. & M. Industries
Trustee	Herbert Roushkolb, Cleveland Automatic Machine Co.

At that meeting Mr. Foster O. Bennett, Dow Chemical Co., presented a fine paper on "Magnesium Die Casting." He has been followed by a long line of oustanding speakers and experts in the field of die casting and related industries such as Alfred Sugar, Alloys and Chemicals Mfg. Co.; Joe Fox, Doehler-Jarvis; Hugo Becker, Crucible Steel; C. R. Schmidt, E. F. Houghton Co.; Dave Morgenstern, Nelmor Mfg. Co.; Wm. Sundwick, Ternstedt, and many others, some of whom have addressed more than one chapter.

September 1, 1954—Meeting of the original 11 men; Park Shelton Hotel, Detroit.

October 4, 1954—1st Official meeting; Veteran's Memorial Building, Detroit.

June 10, 1955—Western Michigan Chapter formed; Inman's Restaurant, Galesburg, Mich.

June 15, 1955—Northern Ohio Organizational Meeting; Bank Grille, Norwalk, Ohio.

January 24, 1956—Chicago Chapter formed; Chicago Bar Assn., Chicago, Ill.

February 15, 1956—Cleveland Chapter formed; Manger Hotel, Cleveland, Ohio.

September 12, 1956—1st S.D.C.E. Stag Day; Bob-O-Link Country Club, Detroit.

November 11, 1956—Toledo Chapter formed; Ritz Nite Club, Toledo, Ohio.

That the Society has caught the imagination of many and fills the need of all in die casting and allied arts is evidenced by its remarkable growth. There are members in nearly every state, in Canada, Britain and Australia. In just over two years there are now five chapters with more to be formed soon. Memberships, individual, company and sustaining are steadily increasing. Plans are well underway for a National Exposition in 1960. It is pretty obvious that the Society is here to stay.

ANALYTICAL GATE DESIGN

(Concluded from Page 10)

EXAMPLE IV

Using the dimensions given for the typical casting in Example I, the gate width for magnesium is:

$$L_g\,(\text{max}) = \frac{(5.00\text{ in}^3)}{(0.033\text{ sec})(0.030\text{ in})(250\text{ fps})(12)} = 1.67\text{ in.}$$

This value compares with a gate width of 0.70 in. for the aluminum.

The minimum plunger velocity using a 2.0 inch diameter plunger will be:

$$V_p\,(\text{min}) = \frac{(5.00\text{ in}^3)(5)}{(0.033\text{ sec})(3.14\text{ in}^2)} = 236\text{ ft/min.}$$

This value is considerably higher than the minimum plunger velocity of 80 fpm for the aluminum.

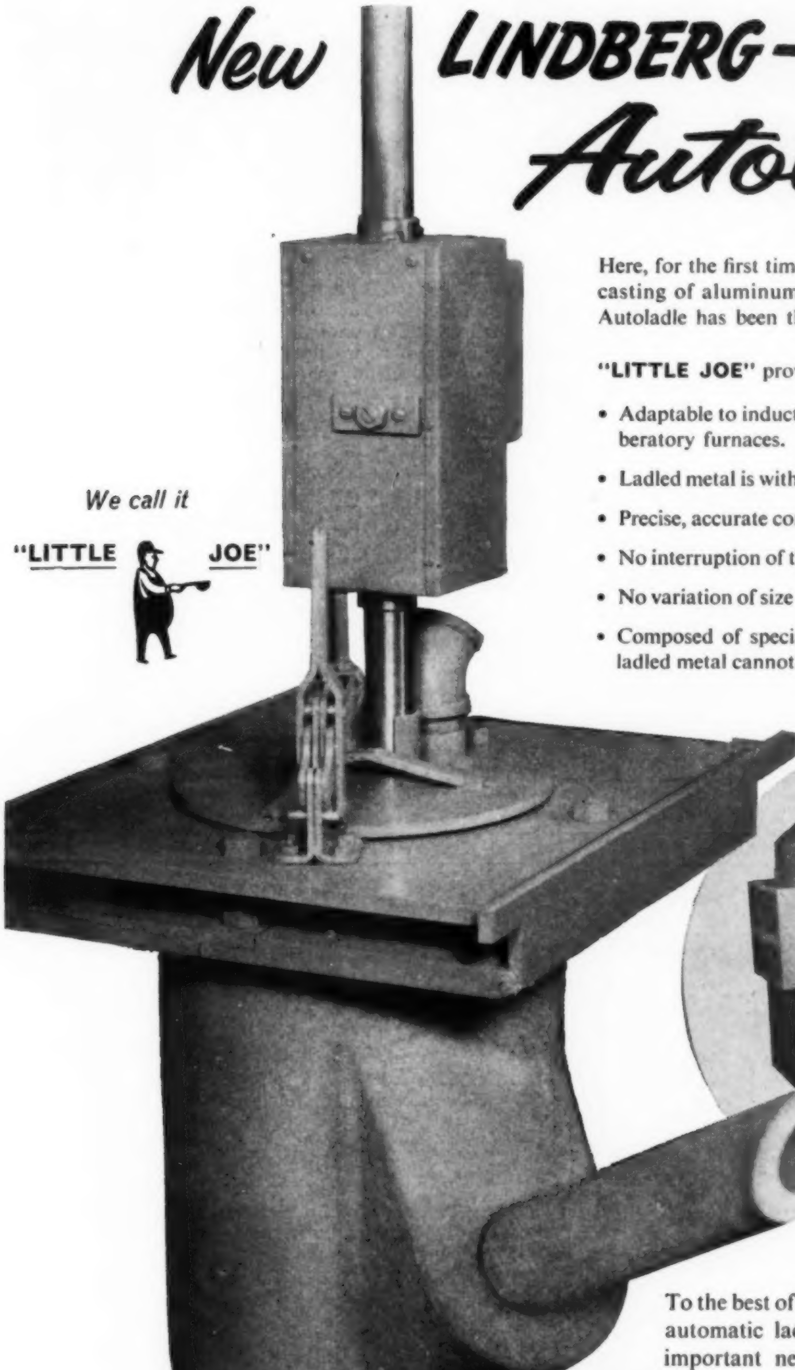
V_p (max) and the minimum and maximum gate velocities may be established by substitution in relations (3), (4), and (5).

The formulations *can* be used to establish gate size and plunger velocity. However, since data is not available on freezing rates, and since these necessarily vary with the die temperature, metal temperature, alloy, and the water cooling arrangement in the die, the die casting engineer must use them only to point the direction in which he should go in changing his gate, metal temperature and plunger velocity. It must be emphasized that the above calculations are as accurate as is our knowledge of the freezing rates of the metal in the die. Unfortunately, there is a marked shortage of published experimental data having to do with freezing rates, pressures developed within the cavity itself, and other phases of molten metal hydraulics and related physical properties. Direct, practical use can be made of such information along the lines proposed in the foregoing discussion. The freezing rates, die temperatures, temperature and possible pressure gradients, and gate temperatures can most certainly be expressed on a phenomenological basis when additional experimental data are made available.

In the absence of such data, the above relations, while being highly empirical, do give a good engineering approximation which will measurably shorten the time between samples and high quality saleable die castings.

1. H. H. Doehler. *Die Casting*, Pages 126-134.
2. Babington and Kleppinger. *ASTM Proceedings*, 1951, "Aluminum Die Castings, the Effect of Process Variables on Their Properties," Page 169.

New LINDBERG-FISHER *Autoladle*



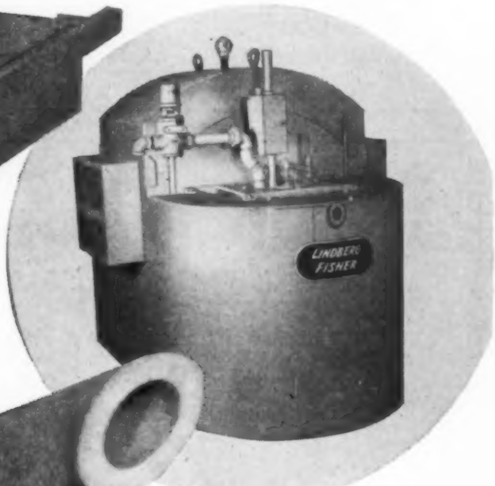
Here, for the first time, is a ladling unit that makes automatic casting of aluminum not only possible but practical. The Autoladle has been thoroughly tested and proven in service.

"LITTLE JOE" provides these advantages:

- Adaptable to induction, electric resistance or fuel-fired reverberatory furnaces.
- Ladled metal is withdrawn from beneath surface of bath.
- Precise, accurate control of any size shot up to 30 lbs.
- No interruption of the casting cycle during charging of metal.
- No variation of size of shot due to metal level changes.
- Composed of special refractory materials so arranged that ladled metal cannot come in contact with any metal.

We call it

"LITTLE JOE"



To the best of our knowledge this is the first practical automatic ladling unit yet devised. It will fill an important need in many casting operations. For complete information, get in touch with your nearest Lindberg Field Representative (see your classified phone book) or write direct.

LINDBERG FISHER **MELTING FURNACES**

A Division of Lindberg Engineering Company, 2485 West Hubbard Street, Chicago 12, Illinois

VACUUM DIE CASTING

(Concluded from Page 15)

when made under vacuum. Die castings now truly become forged castings, with all the benefits of the forging characteristic of the machine showing up. Due to the higher physical strengths in vacuum castings, the wall stock of castings can be materially decreased so as to save weight and cost in production of die castings, making them economically competitive with stampings and opening up new fields to the designer. Where previously wall sections in zinc ran from .050 to .070 and aluminum from .080 to .100, these wall sections can now be drastically cut without losing any physical strength.

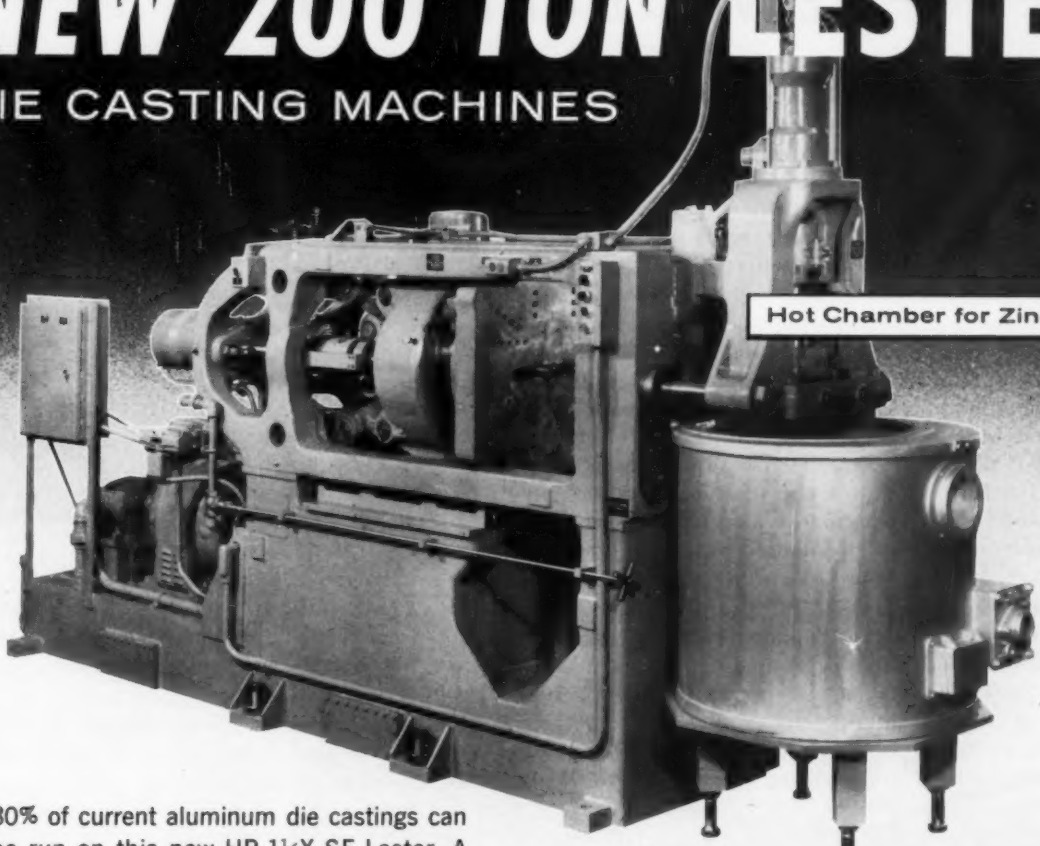
The application of anodizing to give colors in die casting or a durable clear finish is indeed an important development of this process. The economics of running a die cast machine are drastically changed by the step up in speed of operation due to this new valuable tool.

With this new development it is quite obvious that the future of die casting is greatly expanded and will now take a much more important position in the metal working industry. ■ ■ ■

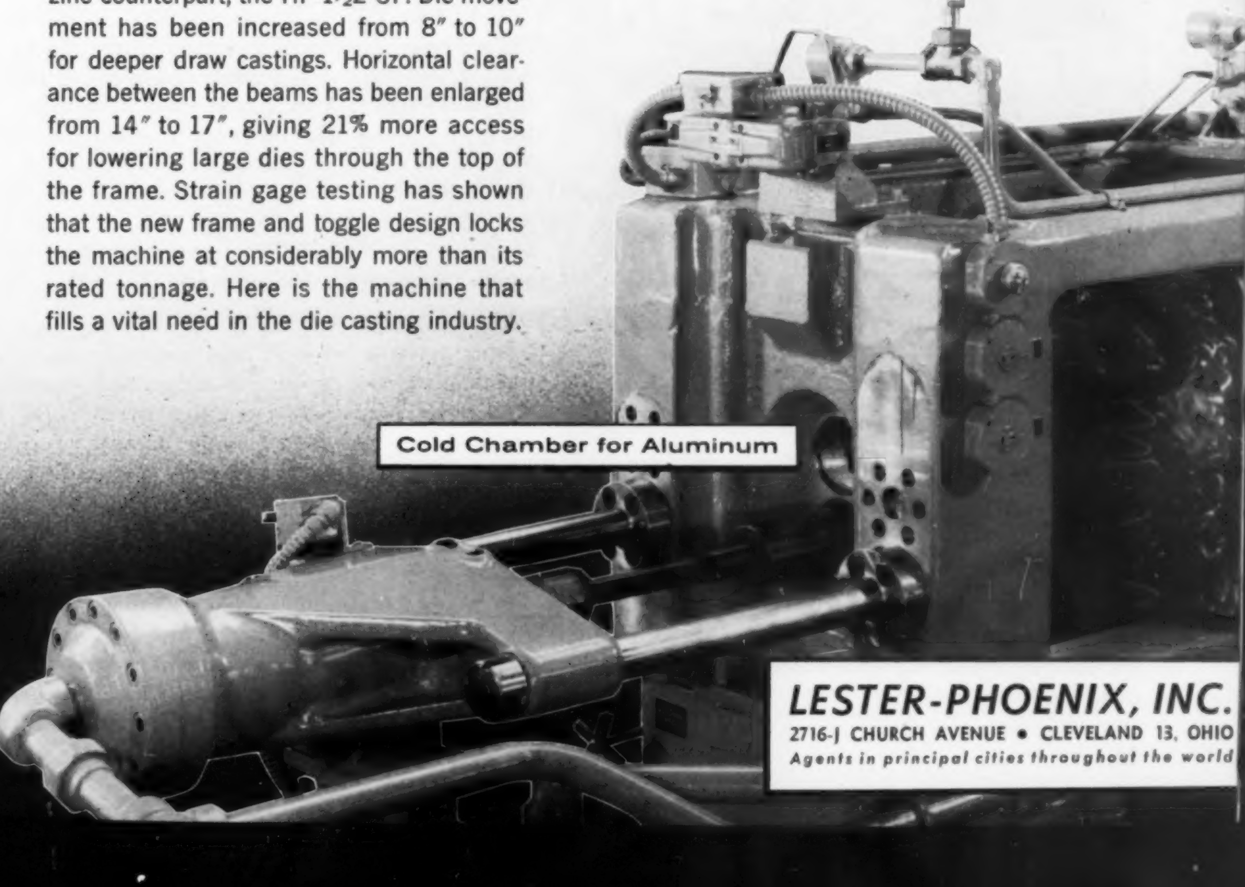
UNIVERSAL HIGH-PRESSURE HYDRAULIC die casting machines, Models 50, 200, 400-N, and 600, producers of precision quality castings under trying around-the-clock production shop operations, are described in a new bulletin published by the Cleveland Automatic Machine Company. Write: 4916 Beech Street, Cincinnati 12, Ohio.

NEW 200 TON LESTER

DIE CASTING MACHINES



80% of current aluminum die castings can be run on this new HP-1½X-SF Lester. A comparable percentage can be run on the zinc counterpart, the HP-1½Z-SF. Die movement has been increased from 8″ to 10″ for deeper draw castings. Horizontal clearance between the beams has been enlarged from 14″ to 17″, giving 21% more access for lowering large dies through the top of the frame. Strain gage testing has shown that the new frame and toggle design locks the machine at considerably more than its rated tonnage. Here is the machine that fills a vital need in the die casting industry.

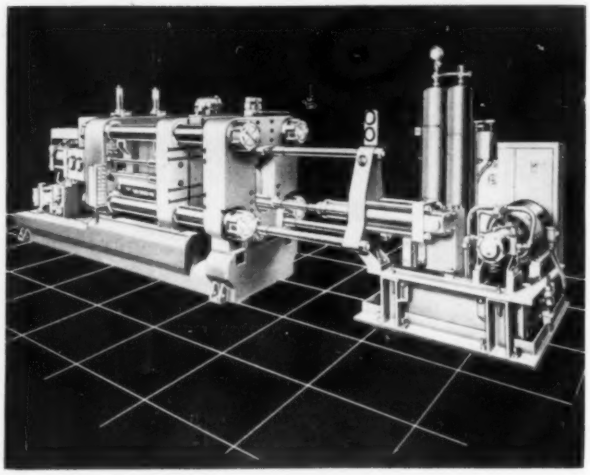


LESTER-PHOENIX, INC.

2716-J CHURCH AVENUE • CLEVELAND 13, OHIO

Agents in principal cities throughout the world

NEW DEVELOPMENTS



The Hydraulic Press Mfg. Co., a Division of Koehring Co., Mount Gilead, Ohio announce a new and improved line of high pressure, cold chamber die casting machines which are the result of two years of proven performance in the field and four years of development and research. These new H-P-Ms are available in 200, 400, 600 and 800 ton capacities. Many refinements in both the self-contained clamp and injection ends have resulted in outstanding performance.

The H-P-M clamp link-wedge locking mechanism, plus the extra heavy platens and tie rods, locks and pre-loads dies to rated tonnage. (Pre-load rated tonnages and superior die locking on press overloads have been proven by test with an 800-ton hydraulic load cell developed by H-P-M). Heavy central screw adjustment is motorized and has push button operation for quick die set-up and tonnage control. Improved locking reduces "wear and tear" on dies and maintains close casting dimensions.

The refined injection end, in addition to the rugged clamp, has made possible the production of the most difficult castings with a minimum of "cut and try" on gates, vents and overflow. This is the result of the compact design of the injection end, its composite features and a unique hydraulic circuit which utilizes special valves and controls. With maximum, ultimate plunger speeds available and positive pressure follow-through from the pump without hesitation, porosity problems, surface finish and "fill" difficulties have been practically eliminated. (Proof tests were made on H-P-M injection with combination mechanical-electronic testing equipment.)

Pressures and press cycle controls are designed for recording so repeat set-ups can be made. All possible safety features are available. ■ ■ ■

ANNOUNCEMENTS

LATROBE STEEL PROMOTES:

Latrobe Steel Company, Latrobe, Pa., has announced the promotion of Stewart G. Fletcher to the position of Vice President-Metallurgy. In his new position, Dr. Fletcher will be responsible for all Metallurgical activities concerned with the products manufactured by Latrobe Steel Company.

Dr. Fletcher has been connected with research and development work on tool steels and allied materials for over fifteen years. After a brief time at the Aluminum Research Laboratories following graduation in Metallurgical Engineering at Carnegie Tech, he entered Graduate School at Massachusetts Institute of Technology in 1939 on a teaching fellowship. This led to the degree of Doctor of Science in Metallurgy, with his major research being on the tempering of tool steels.

During World War II, Dr. Fletcher was engaged in further research on steel heat treatment, working at M.I.T. on several projects concerned with dimensional stability in metals. He was twice, in 1945 and 1949, awarded the Howe Medal by the American Society for Metals for papers growing out of these researches.

In 1945 Dr. Fletcher became associated with Latrobe Steel Company as Chief Research Metallurgist, in 1947 was appointed Chief Metallurgist, and in 1956 became Director of Metallurgy. He has had wide experience in the field of tool and die steels, and has presented numerous lectures on various phases of their manufacture, treatment, and use. ■ ■ ■

Lake Erie Engineering Corp. joins Bell Aircraft Corp. as a subsidiary

Lake Erie Engineering Corporation, Buffalo, N.Y., has been acquired by the Bell Aircraft Corporation, according to an announcement by Presidents Robert E. Dillon of Lake Erie and Leston P. Faneuf of Bell.

As a wholly-owned subsidiary of Bell, Lake Erie will be operated independently; Mr. Dillon continues as president and chief executive officer. There will be no changes in management, personnel, or products.

According to Mr. Dillon, "Association with an organization of Bell's stature offers far greater opportunities in many more respects than does a privately owned company. I know Lake Erie's steady growth will be enhanced and that we will be provided greater latitude of action and a broader base to expand our business and product lines."

Mr. Faneuf states that, "The acquisition of Lake Erie is in line with Bell's policy of diversification in fields outside the defense industry. It will increase our commercial business, add to the strength of our corporation and help stabilize our overall operations."

Lake Erie Engineering Corp. has a worldwide reputation for advances it has pioneered in the complete line of hydraulic presses which it designs and manufactures for all industry. Forming, drawing, forging, die casting, extrusion and molding presses are only a few of the major types of hydraulic equipment manufactured by Lake Erie. The only change in the manufacturing emphasis will be to broaden and improve the present product line.

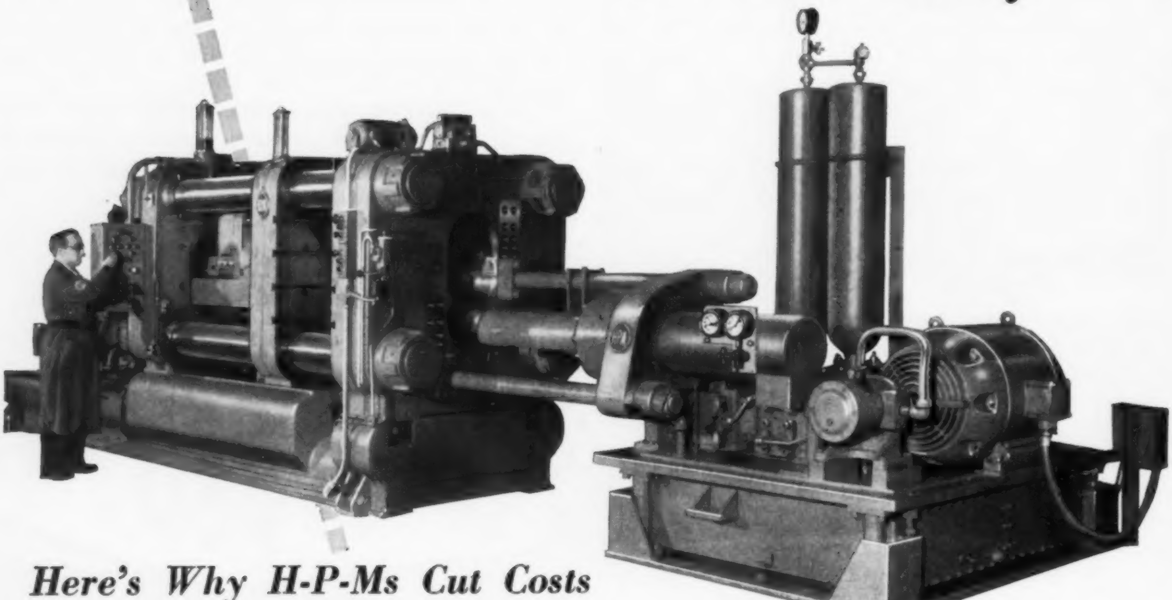
Permanent Mold Die Expands

John W. Wall, president of the Permanent Mold Die Co., Inc., has announced an expansion of the firm's facilities, and a new location for their extrusion die operations at 5749 Beebe Avenue, Warren, Michigan. The new extrusion die plant will be called The PMD Extrusion Die Company, while Permanent Mold Die Company, Inc., will retain its present location at 2275 East Nine Mile Road, Hazel Park, Michigan. ■ ■ ■

ADVERTISERS INDEX

IF YOU DIE CAST . . .

H-P-Ms Give You More For Your Money



Here's Why H-P-Ms Cut Costs Through Better Design

H-P-M die casting machines are the answer to many of today's die casting problems . . . production output to meet any job requirement . . . cleaner castings . . . negligible flash . . . parts produced to accurate dimensional tolerances with improved quality and density. H-P-M's new design, mechanical link wedge clamp and new injection end, results in a new approach to die casting techniques. Here's why H-P-Ms are the best buy:

1. MORE "BEEF"—Heavier platens . . . more die support, less deflection. Larger rods . . . reduced flash, less trimming . . . more casting dimensional control . . . less die trouble.
2. MORE PRESS WEIGHT—Compare price per pound . . . you'll have difficulty finding an equal. In addition . . . H-P-M's many new design features.
3. MORE HORSEPOWER—Clamps to the rated tonnage . . . more pressure cycles per hour . . . higher injection speeds and pressures . . . positive and instantaneous injection follow through.
4. MORE SPEED IN DIE SET-UP—Single central screw adjustment changes daylight and controls tonnage . . . no tie rod nut adjustment.
5. MORE PRESS FLEXIBILITY—No die too complicated or sequence too elaborate. Infinitely adjustable . . . complete control of action, both clamp and injection ends . . . speed and tonnage assured when needed.
6. MORE SAVINGS IN MAINTENANCE—Self-contained clamp and injection ends . . . compact hydraulic power units . . . manifolded high pressure hydraulics . . . automatic lubrication . . . simplicity of mechanical link wedge design.

Write for Bulletin 5400-A, today

DIE CASTING DIVISION

THE HYDRAULIC PRESS MFG. CO.

Mount Gilead, Ohio U.S.A.

HPM

Constitution

PREAMBLE: THE OBJECT OF THE SOCIETY SHALL BE THE IMPROVEMENT AND DISSEMINATION OF THE KNOWLEDGE OF THE ARTS AND SCIENCES OF DIE CASTING AND OF FINISHING OF METALS AND OF ALLIED ARTS; THE DEVELOPMENT OF A COOPERATIVE SPIRIT OF FRIENDSHIP AND MUTUAL ASSISTANCE AMONG ITS MEMBERS.

ARTICLE I

Membership

Section 1. Members: Any person interested in the object of the Society may become a member.

Section 2. Classes of Membership: The Society shall consist of Active Members, Student Members, Sustaining Members, Members at Large and Honorary Members.

Section 3. Active Members: Any person interested in the object of the Society may be elected an Active Member.

Section 4. Student Members: Any person not over twenty-one years of age, regularly enrolled in full time courses at any accredited university or other institution of learning and interested in the object of the Society may be elected a Student Member.

Section 5. Sustaining Membership: A Sustaining Member shall be a person, firm, or corporation who wishes to support and participate in the work of the Society through representatives appointed by him. A Sustaining Member may appoint two such representatives, each of whom is entitled to a single vote. In addition one (1) representative of the sustaining membership may attend one (1) Society board of directors meeting per year, where he may help determine Society policy, but is not entitled to cast a vote on the issue. Where possible the Society shall give recognition to this membership within the national advertising program. A suitable plaque will be issued in recognition thereof.

Section 6. Company Membership: A Company Member shall be a Company, Firm, or trade organization or such other organizations as the Board of Directors may deem appropriate. A company may appoint one representative to represent it and is entitled to one vote. This type of membership is basically to support the local chapters. In return for this support the chapters are to recognize the company members within their advertising range. A suitable plaque will be issued in recognition thereof.

Section 7. Privileges: Student Members shall have all the rights of membership except those of voting and holding office.

Section 8. Chapter Membership: Application for Membership in a Chapter shall be made by the candidate to the Chapter Secretary on the official form accompanied by the application fee. The Chapter Secretary shall submit the application to the Reviewing Board or other established body of the Chapter, which shall investigate the references of the candidate and approve or disapprove the application by majority vote. An approved application shall be submitted to the Chapter for action at the next regular meeting. The Chapter Secretary shall immediately notify the Executive Secretary of the election of any new member.

ARTICLE II

Membership Classifications

Section 1. Producers: A member shall be classified as a producer, providing he is a member of any company, corporation or firm actively manufacturing die castings.

Section 2. Suppliers: Any person who is a member of a company, corporation, or firm that sells any type of a product to the die casting industry or its related arts shall be classified as a supplier.

Section 3. Student Membership: Any person under the age of 21 may be elected as a student member, providing he is enrolled in full time courses at any accredited university or other institution of learning. He may be employed part time at any die casting firm in addition to his educational training.

Section 4. General Interest: Shall be any person who does not enter into any of the other classifications, such as consultants, buyers, members of firms that assemble or use die castings, technical men from other related industries, and institutions.

Section 5. Sustaining Membership: Shall be any corporation, company, or firm that desires to participate in the support of our society.

Section 6. Company Membership: Shall be any organization, firm, company, or institution that desires to participate in the support of a local chapter.

ARTICLE III

Finances

Section 1. Application Fees: The minimum application fee shall be five dollars. Application fee shall be submitted and paid to the Chapter Treasurer. This fee shall be applied towards membership upon election of an applicant or returned upon his rejection.

Section 2. Annual Dues: Payable upon acceptance of the application and effective as of July 1st, yearly thereafter. All dues include the cost of our publication DIE CASTING ENGINEER.

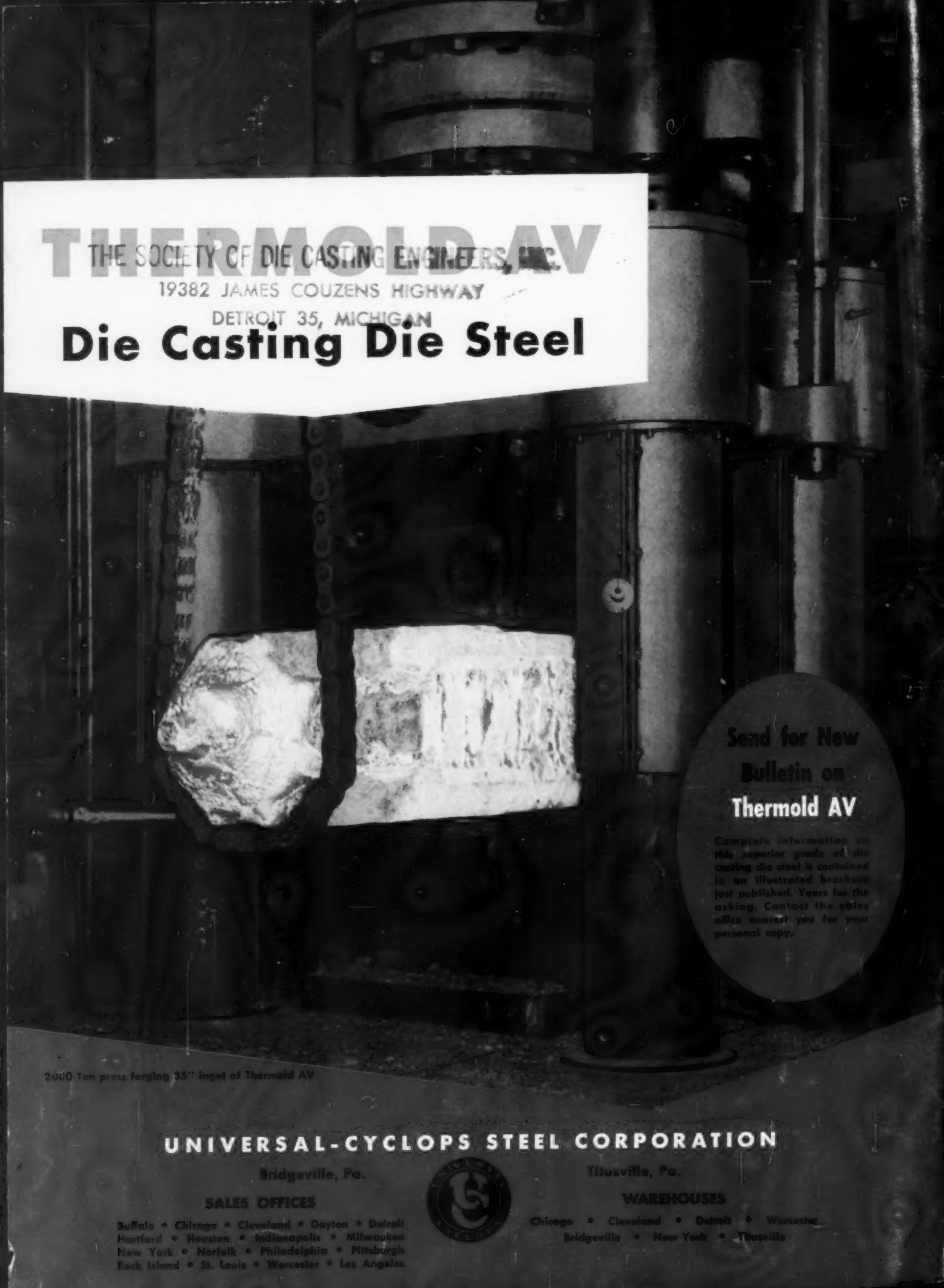
Section 3. Annual Dues of Active Members: shall be fifteen dollars ($15) for his first year and ten dollars ($10) for every year thereafter, providing his membership is renewed within sixty days of his due date.

Section 4. Annual dues of Student Members: shall be five dollars ($5.00) unless he has passed his twenty-fifth (25) birthday and in such case he may be eligible to apply for active membership.

Section 5. The minimum dues for Sustaining Members: shall be a minimum of one hundred-fifty dollars ($150). This membership runs yearly and is effective as of the first of each calendar year.

Section 6. The minimum dues of a Company Member: shall be a minimum of fifty dollars ($50.00). This membership runs yearly and is effective as of the first of each calendar year.

(Revised, 2-15-57)


THERMOLD AV
THE SOCIETY OF DIE CASTING ENGINEERS, INC.
19382 JAMES COUZENS HIGHWAY
DETROIT 35, MICHIGAN
Die Casting Die Steel
Send for New Bulletin on
Thermold AV
Complete information on this superior grade of die casting die steel is contained in an illustrated brochure just published. Yours for the asking. Contact the sales office nearest you for your personal copy.
2000 Ton press forging 35" ingot of Thermold AV
UNIVERSAL-CYCLOPS STEEL CORPORATION
Bridgeville, Pa.
Titusville, Pa.
SALES OFFICES
Buffalo • Chicago • Cleveland • Dayton • Detroit
Hartford • Houston • Indianapolis • Milwaukee
New York • Norfolk • Philadelphia • Pittsburgh
Rock Island • St. Louis • Worcester • Los Angeles
WAREHOUSES
Chicago • Cleveland • Detroit • Worcester
Bridgeville • New York • Titusville